

# OCEAN DIGEST



Quarterly Newsletter of the Ocean Society of India

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### *From the Editors' Desk*

Since its inception in 2014, The Ocean Digest has served as the official newsletter of the Ocean Society of India (OSI), with a mission to connect, inform, and inspire the ocean science community. Published quarterly, in January, April, July, and October- it is freely accessible online and easily shareable across platforms, reaching readers of all ages, including non-members and enthusiasts beyond academic circles.

Over the years, The Ocean Digest has evolved into a vibrant forum for students, early-career researchers, and seasoned professionals to share their work through popular and scientific articles. It bridges the gap between formal research and public understanding, especially in regions where access to scientific journals remains limited. The newsletter thrives on the generous contributions of authors from across India, reflecting the diversity and dynamism of our oceanographic community.

This issue features highlights from OSICON-2025, the 9th National Conference of the Ocean Society of India, held from 5–7 February at the scenic campus of CSIR–National Institute of Oceanography, Goa. The conference, themed “Sustainability of Oceans and Climate Change,” brought together over 600 participants, scientists, students, technologists, and policymakers, to discuss pressing challenges and innovative solutions for ocean health. Sessions ranged from cutting-edge research presentations to the inspiring “Women in Oceanography” forum, celebrating inclusive excellence. Selected papers will be published in a special issue of Ocean Dynamics, further amplifying the impact of this gathering.

As we continue to build bridges across disciplines and geographies, we hope this edition fosters deeper connections among our ocean-loving fraternity. We sign off with warm wishes and a promise to bring you more insights, stories, and voices in our upcoming issues.

Your's Faithfully,  
Rajani and Supriyo  
Editors

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## OSICON- 2025: A Report

The Ninth National Conference of the Ocean Society of India (OSICON-25) was held at CSIR – National Institute of Oceanography, Goa, from February 5-7, 2025. Organized by the Ocean Society of India (OSI) in collaboration with CSIR-NIO; the conference was a flagship event marking CSIR-NIO's Diamond Jubilee. This prestigious, biennial event witnessed enthusiastic participation of 682 delegates representing over 90 premier academic and research institutions across India, including IITs, NITs, CSIR labs, government agencies, and private organizations. Of the 570 scientific abstracts received, 488 were accepted for presentation after rigorous peer review, ensuring high-quality scientific discussions. Over 20 sponsors from industry and academia generously supported the conference, playing a crucial role in the successful execution of OSICON-25.

The focal theme of OSICON-25, "Sustainability of Oceans and Climate Change", underscored the significance of ocean conservation amid climate challenges. The conference covered diverse topics under eleven key themes, including Geological-, Physical-, Chemical- and Biological Oceanography, Ocean Engineering, Ocean-Atmosphere Interactions, Polar Science, Remote Sensing, Marine Microbiology and Ocean Modeling.

The Hon'ble Chief Minister of Goa, Dr. Pramod Sawant, inaugurated the event. He emphasized the critical role of oceans in regulating global climate and the urgent need for sustainable practices. In his address, he highlighted Goa's contributions to ocean research and invited scientists to explore the state's scientific and cultural heritage. He also spoke about India's Deep Ocean Mission and the Samudrayan project, which have been allocated ₹4077 crore and ₹600 crore funding respectively in the Union Budget 2025, reaffirming the government's commitment to advancing marine research. The conference souvenir was released during the inauguration followed by the announcement of the prestigious OSI Awards, recognizing outstanding contributions to oceanographic sciences.

The three-day conference brought together some of the brightest minds in marine sciences. More than 100 oral presentations were delivered across multiple venues, along with three dedicated poster presentation sessions. Invited lectures by eminent scientists Prof. Sunil K. Singh, Prof. Kilaparti Ramakrishna, Dr. S. Venkata Mohan, Dr. Kamesh Raju, Dr. G.V.M. Gupta, Prof. Balaji Ramakrishnan, Dr. V.V. S.S. Sarma, Dr. P.A. L. Bharathi, Dr. M.V. Ramanamurthy, Dr. Grinson George, Prof. V. Sundar, Shri E. Pattabhi Ramarao, Dr. A. Suryachandra Rao, Dr. Roxy M. Koll, Dr. H. Biswas, Prof. M.R. Behra, Dr. Ananda K. Das, Dr. Thamban Meloth, Prof. Prasad K. Bhaskaran, Prof. Avijit Gangopadhyay, Dr. T.M. Balakrishnan Nair, Dr. Tune Usha, and industry experts, remained the highlight of OSICON-25, providing insights into the latest advancements in ocean research & climate change. Two special sessions, showcasing 'Women in Oceanography' and the 'Indian Meteorological Society' (IMS) lent unique dimension to the conference, by addressing contemporary issues and interdisciplinary collaborations.

Each day of the conference brought forward new perspectives and engaging discussions. Following the inspiring inaugural function, technical sessions and poster presentations on Remote Sensing, Marine Biology, Geological Oceanography and Geophysics, occupied the first day. The second day delved deeper into specialized themes, with extensive discussions on Physical-, Biological-, and Chemical Oceanography, Ocean Engineering and Polar Sciences. A dedicated session was organized to assess the OSI Best PhD Thesis and PG Dissertations, providing a platform to budding oceanographers to showcase their outstanding research contributions. The final day commenced with the session on 'Women in Oceanography' which discussed challenges and opportunities for women in marine sciences, followed by the sessions on Ocean-Atmosphere Interactions and Ocean Modeling. The event culminated in a grand Valedictory Function, featuring the esteemed N.K. Panikkar Memorial Lecture delivered by the Director of CSIR-NIO, Prof. Sunil Kumar Singh. The three-day event culminated with the announcement of the OSI awards recognizing the best oral and poster presentations across all themes. OSICON-25 ensured seamless logistical support for its participants; about 200 young research scholars, temporary project staff, and 30 senior researchers were provided free accommodation in hotels and guesthouses within a 5 Km. radius of the venue and were provided transport to and from the conference.



Inauguration of OSICON-25 at the hands of hon'ble Chief Minister of Goa, Mr. Pramod Sawant



The OSICON-25 awardees pose for a picture with Director CSIR-NIO Dr. Sunil Singh and office bearers of OSI



**The inaugural session was held in the iconic shell shaped Dr. S.Z. Qasim auditorium of CSIR NIO**

*Select, full-length research papers, presented at the OSICON- 25 and following peer-review shall be published as a Special Issue of the Conference Proceedings, shortly from now. The volume shall be guest edited by representatives of CSIR-NIO, OSI and IIT-Kharagpur and Dr. Gangopadhyaya as the corresponding editor. The call for paper submissions is open until September 30, 2025.*

## OSI Awardees at OSICON-25



**OSI Honorary Fellow**  
Dr. SWA Naqwi  
Former Director  
CSIR-NIO



**OSI Fellow**  
Dr. Baba M  
Former Director, CESS,  
Trivandrum



**OSI Fellow**  
Prof. V. Sundar  
Emeritus Professor, IIT  
Madras



**Dr. D. Srinivasan  
Endowment Award**  
Dr. R. R. Rao  
Former Scientist-G,  
NPOL, Kochi



**Prof. R. Ramesh  
Endowment Award**  
Dr. Roxy Mathew Koll  
Scientist F, IITM-Pune

OSICON-25 proved to be a remarkable platform for knowledge exchange, fostering collaborations and discussions on ocean sustainability and climate resilience. The overwhelming participation and high-quality research presented, reaffirmed its status as India's premier oceanography conference. With the formal announcement of OSICON-27 to be hosted at Indian Institute of Tropical Meteorology, Pune, the momentum for advancing marine science and sustainability continues, promising greater scientific contributions and impactful research in the years ahead. The conference concluded on a high note, leaving a lasting impact on the oceanographic research community and reinforcing the need for continued efforts toward a sustainable future of the oceans.



Conference Photograph OSICON-25

## Budding Oceanographer Awardees at OSICON-25

### Best PhD Thesis Sponsored Awards

1. Dr. H.N. Siddiqui Award in Geological Oceanography: **Dr. Aswini K.K.** (Geodynamics of Andaman Sea) – Goa University
2. Dr. N.P. Kurian Award in Physical Oceanography: **Dr. Athira Krishnan** (Wind waves in the Indian Ocean) – IIT Kharagpur
3. Prof. A.D. Rao Award in Oceans and Atmosphere: **Dr. Vineet Kumar Singh** (Tropical cyclone interactions) – Savitribai Phule Pune University
4. Dr. Shanta Achuthankutty & Dr. P.A. Lokabharathi Award in Marine Microbiology and Biotechnology: **Dr. Femi Anna Thomas** (Bacterial diversity in the Arctic) – Goa University
5. Dr. (Mrs.) N.I. Joseph & Prof. K.V. Jayachandran Award in Biological Oceanography: **Dr. Kanchan Sambwani** (Red seaweed characterization) – CSIR-CSMCRI
6. Prof. Vallam Sundar Award in Ocean Engineering: **Dr. Aruna M.V.** (Autonomous underwater vehicles) – IIT Madras
7. Dr. Rabindranath Sengupta Award in Chemical Oceanography: **Dr. Apurva P. Joshi** (Carbonate variability in the Bay of Bengal) – IIT Kharagpur

### Best PG Dissertation Awards by OSI

1. Moulik Mandal (Marine Heatwave over North Bay of Bengal) – NIT Rourkela
2. Pranali P. Marbade (Salinity adaptability in pearl spot fish) – IFPGS, Chennai
3. Kalpana B. Prusty (Microplastics in Bombay duck) – H.N. Gujarat University
4. Anusri Saha (Sea surface temperature reconstruction) – IIT Bhubaneswar
5. Aharna Sarkar (Tree-ring proxies for ecosystem productivity) – IISER Pune

### Best Oral Presentations Sponsored Awards

- Geological Oceanography (by Shri. Kesavadas): Mr. Pavan Miriyala
- Physical Oceanography (by Dr. M. Baba): Mr. Sudeep Das
- Chemical Oceanography (by Shri. C.V.G. Reddy): Ms. Safia Khan
- Biological Oceanography (by Late Prof. N.R. Menon): Dr. Manikandan B
- Ocean Engineering (by Prof. V. Sundar): Ms. Sandana Socrates S
- Oceans and Atmosphere (by Prof. A. D. Rao): Mr. Arulalan T

### Best Oral Presentations Awards

- Marine Microbiology & Biotechnology: Ms. Athira Menon T
- Polar Science: Mr. Ahammed Shereef M.S.
- Remote Sensing & In-Situ Observations: Ms. Pooja Patel
- Marine Geophysics: Dr. Jensen Jacob
- Ocean Modelling: Dr. Remya Remabhai

### Best Poster Presentations Awards

- Geological Oceanography: Ms. Maria Fernandes
- Marine Geophysics: Mr. Saif Ali Khan
- Physical Oceanography: Mr. Ashish K Sasidharan
- Chemical Oceanography: Mr. Balaram Sahu
- Biological Oceanography: Mr. Vishal C.R & Mr Lawrence I
- Ocean Engineering: Ms. Megha Sunil & Mr. Rambabu Nimma
- Oceans and Atmosphere: Mr. Devbrat Harma
- Marine Microbiology & Biotechnology: Ms. Pratika Singh
- Polar Science: Ms. Anju Chalari
- Remote Sensing & In-Situ Observations: Mr. Vikarnth
- Ocean Modelling: Mr. Sreeraj

### Pteropods: Bio-indicators of Ocean Acidification

Student Article



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Pteropods are a group of marine gastropods that spend their entire lives swimming and drifting in the open ocean which is a major sink of anthropogenic CO<sub>2</sub>. Hence, they are vulnerable to ocean acidification (OA). Pteropods are Gymnosomatous (non-shelled) and Thecosomatous (shelled). They are also referred to as sea angels and sea butterflies respectively. A marine-geologist is particularly interested in shelled pteropods because their shells get deposited on the ocean floor and get preserved in the sediments after they die, which serve as proxies in palaeoceanographic studies.

Shelled pteropods build thin and light shells of aragonite, a metastable polymorph of calcium carbonate that can be 50% more soluble in seawater than calcite (Mucci, 1983). Thus, studying their distribution and state of preservation in ocean waters and sediments, give insights into aragonite dissolution caused by OA. Over the past decade, research has shown that low pH conditions lead to reduced calcification and shell dissolution in pteropods. Field observations have confirmed this, revealing a direct correlation between thinner shells and lower aragonite saturation states (Bednarsek et al., 2017). As a result, pteropods are increasingly used as biological indicators to assess the impacts of OA (Bednaršek et al., 2014; Manno et al., 2021).

Pteropods are typically preserved in sediments above the Aragonite Compensation Depth (ACD) between 240 m and 3400 m, which varies from ocean to ocean (Panchang & Ambokar, 2021). Their distribution is influenced by various environmental factors including temperature, salinity, oxygen concentration, biological productivity and water depth. Current pteropod populations vary latitudinally, from cold polar to warmer equatorial waters, suggesting temperature to be the most important factor controlling its diversity and distribution. However, in the Mediterranean, pteropod abundances decrease along a salinity gradient (from the west characterised by moderate salinity to the eastern sectors, where salinity is higher) (Johnson et al., 2023). This trend suggests that, for some species, salinity may play a more critical role than temperature. Some pteropod species have also adapted to low-salinity and low temperature environments (Fransson et al., 2022).

Shelled pteropods display species-specific distribution patterns that vary with oceanic changes, as each species exhibits a distinct ecological niche and is also biologically sensitive to even slight alterations in ocean chemistry (Ambokar et al., 2022; Panchang et al., 2023). Additionally, the physical; state (while floating in the water column) and preservation state of their shells (when deposited on the ocean floor) are used as indicators to reconstruct past OA events. Their preservation state can be evaluated by examining shell condition and transparency, along with population abundance and diversity. Four main preservation states have been identified and described by Almogi Labin et al. (1986) (Fig.) and has been widely used successfully in palaeoclimatic reconstructions (Klocker et al., 2007; Naidu et al., 2014; Sijinkumar et al., 2015).

· Stage 1 (Healthy): Transparent, undamaged shells found in low-stress environments. Populations are typically abundant and diverse.

· Stage 2 (Slight Stress): Translucent shells indicating slight corrosion, typically occur in areas with mild acidification or other stressors.

· Stage 3 (Moderate Stress): Shells become white or opaque due to significant corrosion, indicating moderate environmental stress.

· Stage 4 (Severe Stress): Extensive dissolution leaves only casts or moulds of shells; found in highly impacted regions and associated with population collapse or local extinction risk.

Thin aragonitic Pteropod shells dissolve rapidly when seawater becomes undersaturated with respect to aragonite i.e. when the aragonite saturation state ( $\Omega_{\text{arag}}$ ) drops below 1. Since  $\Omega_{\text{arag}}$  is closely linked to pH, even a small decline in pH can trigger shell dissolution. Pteropod shell surface damage can be observed under the microscope or by SEM imaging; the heavily corroded shells indicate exposure to corrosive conditions, making pteropods an early-warning indicators of OA.

At present, ocean acidification trends are tracked through a combination of shipboard surveys, biogeochemical (BGC) Argo floats, and moored buoys. Moorings are fixed platforms equipped with sensors, while BGC-Argo represents a global fleet of autonomous drifting floats, both providing high-quality in situ pH records. In the Indian Ocean, pH monitoring is carried out at two scales. Along the coast, the Ministry of Earth Sciences, Government of India has been running the COMAPS program since the early 1990s, generating one of the longest coastal OA datasets.

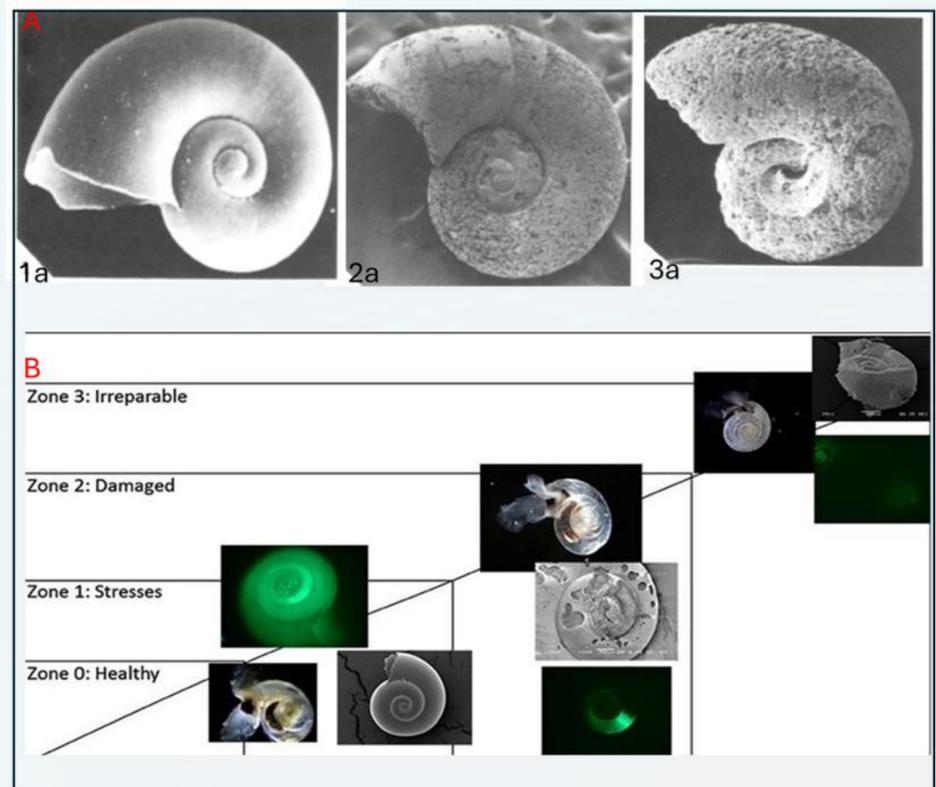


Fig. 1. The figure shows different degrees of preservation of Pteropods used to reconstruct past changes in ACD to study degree of preservation in live pteropod specimens; (A) SEM images of different states of preservations of pteropods from sediment core samples. 1a – well preserved transparent shell; 2a – white aragonite shell with internal cast; 3a – internal cast without shell. (B) Microphotographs of recent plankton tow sampled specimens with SEM and fluorescence light images.

In the open ocean, pH observations are collected through moored arrays such as OMNI and RAMA, along with BGC-Argo deployments under the IndOOS framework. Instrumental datasets from these programs are accessible via the INCOIS data portal, providing valuable resources for understanding both regional and global OA trends. Beyond modern observations, past changes in seawater pH are also be reconstructed using geochemical proxies such as boron isotopes ( $\delta^{11}\text{B}$ ). **Pteropods are unique in serving as both, a proxy for reconstructing past pH variability and a biological monitor of ongoing OA.**

Due to the vulnerability of their aragonitic shells to environmental changes, particularly ocean acidification, pteropods are of growing concern within the scientific community. Pteropods are particularly important in high-latitude regions, such as the Southern Ocean and areas with upwelling, where are they important components of the marine food-web at the base of the food chain. Any shift in their abundance can have far-reaching, cascading ecological effects, as they serve as an essential food source for fish, birds, whales, and other marine organisms (Weldrick et al., 2019).

Furthermore, decline in their population can disrupt the ocean's carbon and carbonate cycles. As they sink into the ocean and get buried within sediments, they sequester carbon for long durations of time. Pteropods are a major contributor to the oceanic carbonate budget; approximately 12% of aragonite production in the global ocean is derived from pteropods. They are estimated to contribute at least 33% to the export of CaCO<sub>3</sub> at 100 meters depth and can account for up to 89% of pelagic calcification (Buitenhuis, 2019).

Past records indicate that pteropods have existed since the Early Cretaceous and have survived major episodes of environmental change such as oceanic anoxic events, sea level changes, ocean circulation changes, and ocean acidification, including the Cretaceous-Paleogene extinction event (K-Pg) 66 million years ago and the Paleocene-Eocene Thermal Maximum (PETM) 56 million years ago, which closely resemble the current CO<sub>2</sub>-driven climate change. This suggests that pteropods may be more resilient to global change than previously assumed, also, making them an excellent proxy to reconstruct the past records of ocean acidification.



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### Confirming the Potential Utilization of Life History Phases of *Gracilaria dura* for Harnessing industrial-scale Farming



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The global agar industry produces approximately 14,500 tons annually, valued at US\$246 million, requiring 1,25,200 tons of dry seaweed biomass (Mantri et al., 2022). This industry is currently undergoing a significant shift. Once dominated by the feedstock of red seaweed *Gelidium*, the market is increasingly turning to a species of another red seaweed genus *Gracilaria*. This change is driven by declining wild stocks of *Gelidium* and the practical challenges of cultivating it. On the contrary *Gracilaria* is amenable to commercial farming and several species are cultivated commercially (Porse & Bixler, 2017). Among these, *Gracilaria dura*, is gaining attention for its ability to yield high-quality agarose.

CSIR-Central Salt & Marine Chemicals Research Institute (CSMCRI) has developed an energy-efficient, environmentally friendly process for direct agarose extraction from feedstock (Siddhanta et al., 2005). CSIR, New Delhi has secured the trademark for this product "Sagarose" (Trade Mark No. 2123313). Agarose is widely utilized in niche applications, making it the preferred choice in the domains of biotechnology, molecular biology, medical research, forensic science, etc.

The triphasic life history of *Gracilaria dura*, with its isomorphic tetrasporophyte and gametophytes (male and female separate stages), presents ample opportunity for selective breeding and cultivar development to boost productivity and economic viability. To explore this, we conducted a comparative study by collecting different life history stages of this seaweed during January to March, for assessing key traits such as growth, yield, biochemical composition, pigments, and antioxidant capacity.

The study revealed distinct advantages associated with specific life history stages, that can be exploited to derive the benefits for sustainable commercial farming. Tetrasporophytes showed faster growth and greater productivity, making them ideal for large-scale biomass generation. On the other hand, female gametophytes excelled in biochemical richness, including higher concentrations of proteins, pigments, and antioxidants, making them better in terms of seedling survival and regeneration (Fig. 1). These differences led us to propose a concept: Commercial farming should begin with seedlings derived from the stock of gametophytes while later farmers can shift towards using tetrasporophytes to enhance final biomass yield (Sambhwani et al., 2020).

The pre-commercial farming was attempted at the Simar coast of Gujarat (near Diu Island) and the existence of significant physiological (Fig. 2) and biochemical (Table 1) divergence between the life-history stages was confirmed in this species (Mantri et al., 2021). Further, continuous use of the same cultivation over the past 5–7 years in this species by farmers of this region has led to the involuntary domestication of better strains. This cultivar now exhibits improved phenotypic traits under human-managed environmental conditions. Comparative analyses between wild and cultivated populations indicated that domesticated strains possessed enhanced functional traits, including higher daily growth rate (DGR), improved photosynthetic efficiency, and greater survival rates, as evidenced by relevant biochemical characterisation. Moreover, agar yield and quality parameters were also found to be superior in cultivated strains, suggesting the emergence of elite cultivars through long-term farming practices and natural selection by farmers (Sambhwani et al., 2022a)

To deepen our understanding of phase differentiation at the molecular level, transcriptomic analyses were performed. Differential gene expression profiling using RT-PCR revealed distinct expression patterns related to stress response and growth, underscoring the physiological divergence between these stages. The simple sequence repeat (SSR) markers were developed and validated to enable early-stage identification of life-history phases, which is crucial for optimized farming and seedling selection before the thallus maturity (Sambhwani et al., 2022b).

Our research of life-history based functional differentiation in *Gracilaria dura* led to successful international collaboration with the only other research group namely, Marine Environment and Technology Centre (MARETEC), Instituto Superior Tecnico, Universidade Tecnica de Lisboa, Lisbon, Portugal, that is engaged in this domain. This collaboration expanded the dataset spatially and temporally, thereby confirming our initial findings across broader sample sizes and environmental conditions (Dawange et al., 2023; Vieira et al., 2024).

Parallel research into improving seedling production methodologies revealed two viable approaches: regeneration via carpospores and clonal propagation. While carpospore-based seedling production suffers from high mortality rates due to predation and the inherent slow growth of sporelings, clonal propagation has been successfully implemented in tank-based systems. Notably, the first large-scale cultivation of 25,000 clonal seedlings of this species was achieved between 2021 and 2023 in collaboration with the Indian Centre for Climate and Societal Research, with partial funding support from the National Fisheries Development Board (NFDB) and DST-TIFAC (Balar et al., 2025).

Life-history-based selection of *Gracilaria dura* seedlings, guided by biochemical and physiological traits, offers a promising approach to improve cultivation sustainability and economic viability of the process. This initiative has attracted industry interest, with feedstock from CSIR-CSMCRI farms showing encouraging results in trials by downstream processors. The seedling produced through these interventions are now propagated in large numbers and given to the seaweed farmers of Gujarat. M/s. Pidilite Industries, through their CSR initiative at the Centre for Agriculture-Horticulture Development, Manar, has trained 250–300 fishermen and plans to expand farming this species along the entire Gujarat coast.

In conclusion, our integrated study of the physiological, biochemical, and molecular traits across life-history stages of *Gracilaria dura* provides a strong foundation for life-stage-specific cultivation strategies. The domestication of elite strains and the successful demonstration of large-scale clonal propagation, mark significant milestones toward establishing a sustainable and economically viable *Gracilaria*-based agarose industry in India.

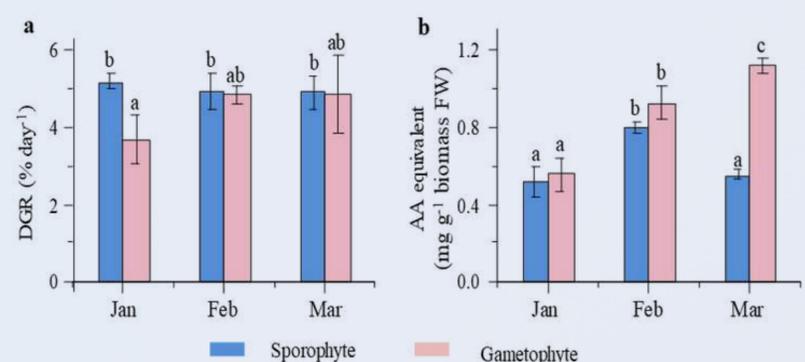


Fig.1 (a) Daily growth rate (DGR) over 15 days for acclimatized field material under lab conditions (25°C, 55 μmol photons m<sup>-2</sup> s<sup>-1</sup>, 12 h light, 35 psu salinity). (b) Total antioxidant activity (as ascorbic acid equivalents) from field-collected biomass. Different letters indicate significant differences between life stages (ANOVA, p < 0.05). Data are mean ± SD (n = 3).

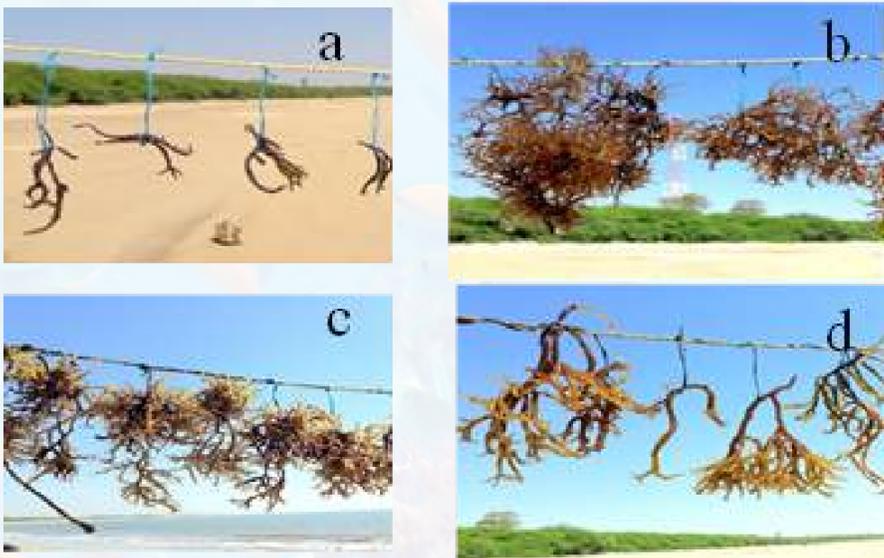


Fig. 2: Life history phases-based farming in open sea. a Seeded monoline initial (day 0). b Male plants harvesting stage, c Tetrasporophyte plants harvesting stage, d Female plants harvesting stage at 24 days

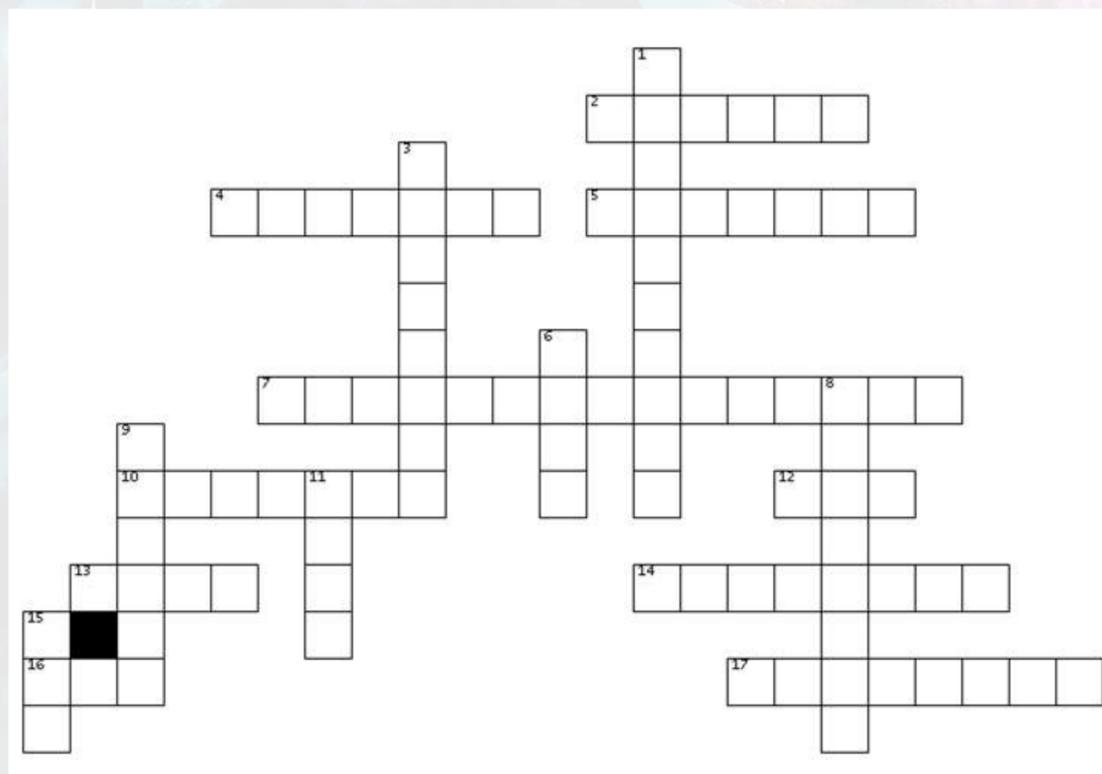
Life history stage	Growth	Agar characterisation					
	DGR (% day <sup>-1</sup> )	Yield (%)	Gel Strength	Ash (%)	Sulphate (%)	Gelling Temp.	Melting Temp.
Tetrasporophyte	5.10 ± 0.14b	28.6 ± 1.53b	1900 ± 50 a	1.01 ± 0.09 a	0.36 ± 0.05 a	38 ± 1 a	91 ± 2 a
Male	6.23 ± 0.59c	25.2 ± 0.36a	2384 ± 124.13b	0.94 ± 0.11 a	0.28 ± 0.03a	38 ± 2 a	91 ± 2 a
Cystocarpic Female	2.66 ± 0.32a	27.4 ± 0.60ab	2122 ± 124.03ab	0.96 ± 0.06 a	0.30 ± 0.04 a	38 ± 1.73 a	90.66 ± 1.15 a

Table 1 Daily growth rate (DGR) and properties of agarose extracted from cultivated biomass of male, cystocarpic female and tetrasporophytic thalli

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### Crossword Puzzle: Indian Ocean and Climate



#### ACROSS

- Southern Indian Ocean climatic oscillation affecting Australia and Africa
- Dominant seasonal wind system influencing South Asian climate
- Sediment feature recording monsoonal wind strength over millennia
- Process by which oxygen is depleted in mid-depth ocean waters
- Indian Ocean region where surface productivity is enhanced by eddies
- Indian Ocean circulation pattern analogous to ENSO
- Mineral proxy often used to reconstruct sea surface temperatures
- Low-pressure system over the Bay of Bengal in pre-monsoon months
- Geological period known for low sea level and glacial expansion
- Remote sensing satellite used to study ocean color and productivity

#### DOWN

- Warm surface current originating from the western Pacific into the Indian Ocean
- Major eastern boundary current in the western Indian Ocean
- Wind-driven current flowing along Indian west coast during summer monsoon
- Paleoceanographic proxy from foraminifera shells
- Monsoon-fed river known for high freshwater discharge into Bay of Bengal
- Atmospheric cell influencing rainfall across equatorial Indian Ocean
- Large-scale subsurface water mass with low oxygen content

### Healing Potential of the Seaweeds *Sargassum wightii* and *Turbinaria conoides* Against Gastric Ulcers Induced by HCl/Ethanol in Wistar Rats



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#### Abstract

Knowing that marine algae are valuable sources of structurally diverse bioactive compounds, the present study examined gastroprotective activities of *Sargassum wightii* and *Turbinaria conoides* from Gulf of Mannar in ulcer induced rats. The algae were found to have significant anti-secretory activity as evidenced by decreased gastric fluid volume, total acidity, and increase in the pH of the gastric fluid in ethanol/HCl induced rats. Our studies also revealed that pre-treatment with supercritical fluid extract of brown seaweeds (at a dose of 0.5g/kg) significantly reduced the number of ulcers, ulcer score and ulcer index in ethanol/HCl treated rats. The anti-ulcer activity of brown seaweeds was validated by histopathological study, which showed protection of the mucosal layer from ulceration. Furthermore, these seaweeds showed significant reversal of ethanol-diminished activity in antioxidant enzymes, such as superoxide dismutase (SOD), catalase (CAT), and glutathione (GSH). The ulcer inhibition was found to be 80% at a dose of 0.5g/kg. The results show that the SOD, CAT, and GSH levels in the ethanol treated groups were significantly lower than that of the control group. Increase in pH and reduced gastric volume is highly correlated with effective anti-ulcer activity. The overall findings conclude that extracts of *Sargassum wightii* and *Turbinaria conoides* have significant anti-ulcer effects. Hence, the present study suggests that these brown seaweeds may be a potential natural source of biomolecules for the prevention and treatment of gastric ulcer.

#### 1. Introduction

Gastric ulcer is a very common disease in society and severely affects 3-4 million people around the world each year (Zelickson et al., 2011). The chemistry of gastric ulcers is not fully known. Gastric ulcers are known to develop due to the imbalance between some factors like stress, nonsteroidal anti-inflammatory (NSAID) drugs, *Helicobacter pylori* infection, etc. and some defense mechanisms like bicarbonate efflux, raised antioxidant levels, prostaglandins, nitric oxide and sulphhydryls (Wallace, 2008; Junior et al., 2014; Yuan et al., 2006). Major treatment for gastric ulcer includes prostaglandin analogues, gastroprotective agents, histamine receptor antagonists and proton pump inhibitors (PPI) (Chan & Leung, 2002; Malferteiner et al., 2009). The most effective treatment for the gastric ulcers is the proton pump inhibitor. Proton pump inhibitors (PPIs) reduce the amount of acid produced by the stomach, thereby reducing the irritation of the stomach lining, allowing ulcers to heal (Gisbert et al., 2001). These present therapies can cause serious side effects such as hypersensitivity, arrhythmia and serious hematopoietic disorders (Malferteiner et al., 2009; Sheen & Triadafilopoulos, 2011). There is a need to discover novel, more effective and safer treatments for gastric ulcer, with fewer side effects.

As per published scientific literature, a significant number of bioactive compounds have been discovered from the marine environments. Among these, seaweeds and macroalgae are considered to be rich sources of bioactive compounds suitable for therapeutic and medical applications, promoting the exploration of marine resources for drug discovery. Seaweeds have been a source of food, feed and medicine since ancient times. Being plants of unique structure and biochemical composition, seaweeds in India have been used for industrial production of agar, alginate and fertilizers. However, their medicinal, nutraceutical and cosmetic potential has not yet been explored to the fullest.

Seaweeds are also a major source of sulphated polysaccharides and other bioactive compounds like alginic acid and carrageenan. The distinctive seaweed resources of the Gulf of Mannar, Southeast coast of India are mainly used in the production of phycocolloids. The biomedical and nutritional importance of these seaweeds has not received much attention. So, the seaweeds *Turbinaria* and *Sargassum* were selected based on preliminary screening (data not shown) and evaluated for pharmacological activity such as anti-ulcerous activity. In view of all of the above factors, the present study was undertaken to assess the anti-ulcer activity of selected seaweed extract on ethanol/HCl induced ulceration in Wistar rats.

#### 2. Materials and Methods

##### 2.1 Sample collection and extraction

##### 2.2 Animals

Seaweeds (*Sargassum wightii* and *Turbinaria conoides*) were collected from Mandapam, Tamil Nadu, India. Extraction was achieved by supercritical fluid extractor (briefly, 100 g of powdered seaweed sample was compacted in a 1 L extraction vessel. The flow rate of CO<sub>2</sub> was fixed at 30 g/min. Ethanol was employed as co-solvent at the rate of 6% (2 g/min), pressure 250 bar, temperature 50 °C and extraction was carried out for duration of 1 h. After the extraction period, the extracts were collected, vacuum evaporated, re-dispersed in the respective solvents and stored at -20 °C for further analysis.

Wistar strain male albino rats (140-210 g) were used for this experiment. They were grouped individually in special cages in hygienic conditions, maintained at room temperature (28±2 °C) and provided food and water ad libitum. Animal experiments were performed as per the guidelines of the Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA), New Delhi, India and approved by the Institutional Animal Ethics Committee (IAEC), Central Institute of Fisheries Technology (ICAR-CIFT), Cochin, Kerala, India.

##### 2.3 Anti-ulcer activity

Anti-ulcer activity was determined, by the method of Hara & Okabe (1985). Male Wistar rats kept in standard laboratory conditions were randomly assigned to four groups consisting of 6 animals each. Group I (Positive control) received hydrochloric acid-ethanol (0.6% v/v) to induce ulcers while group II acted as negative control and was fed with regular diet only. Group III was pre-treated with *Turbinaria* at 0.5 g/kg body weight prior to induction of ulcer. Group IV was administered with *Sargassum* at 0.5 g/kg body weight and Group V was administered with a standard drug. All the animals were fasted overnight before the induction of ulcer. After 4 hours of induction of ulcer, all animal groups underwent surgery as per the method of Takeuchi et al. (1976). The stomach was inflated with normal saline, then incised and taken for counting the number of lesions and histopathology. Gastric juice was sampled for determining the pH.

The ulcer index was calculated by adding the total number of ulcers per stomach and the total severity of ulcers per stomach (Hollander et al., 1985).

The number and severity recorded for ulcer scores are as follows:

0 = normal stomach; 0:5 = red coloration;

1:0 = spot ulcers; 1:5 = hemorrhagic streaks;

2:0 = > 3 but < 5 ulcers; 3:0 = > 5 ulcers

The mean ulcer score for each animal is expressed as the ulcer index.

The percentage protection is expressed as:

Percentage protection = (induced- treated)/induced \* 100

##### 2.4 Preparation of subcellular fractions of stomachs

The lesion part was weighted and homogenized with 200 mM potassium phosphate buffer (pH 6.5). The homogenate was used to measure the reduced glutathione (GSH) levels and then centrifuged at 11,000 rpm for 20 min at 4 °C. The supernatant was used to establish superoxide dismutase (SOD) and catalase (CAT) activity. GSH levels in gastric mucosa were determined as described by Sedlak & Lindsay (1968). Tissue homogenate previously prepared were mixed with 12.5% trichloroacetic acid and centrifuged for 4000 rpm for 15 min at 4 °C. The absorbance of supernatant plus TRIS buffer (0.4 M, pH 8.9) and 5,5'-dithiobis 2-nitrobenzoic acid (DTNB, 0.01 M) absorbance of the supernatant was measured at 420 nm and expressed as mg GSH/g of tissue.

##### 2.5 Determination of reduced glutathione (GSH) levels

GSH levels in gastric mucosa were determined as described by Sedlak & Lindsay (1968). Tissue homogenate previously prepared were mixed with 12.5% trichloroacetic acid and centrifuged for 4000 rpm for 15 min at 4 °C. The absorbance of supernatant plus TRIS buffer (0.4 M, pH 8.9) and 5,5'-dithiobis 2-nitrobenzoic acid (DTNB, 0.01 M) absorbance of the supernatant was measured at 420 nm and expressed as mg GSH/g of tissue.

##### 2.6 Determination of superoxide dismutase (SOD) activity

The activity of SOD was determined as described previously by Marklund & Marklund (1974). Aliquots of tissue homogenate were mixed with Pyrogallol (1 mM) and buffer solution (Tris HCl 1 mM – EDTA 5 mM, pH 8.5). The reaction was incubated for 20 min, stopped with the addition of 1 N HCl and then centrifuged for 4 min at 14,000 rpm. The absorbance of the supernatant was measured at 405 nm. The amount of SOD that inhibited the oxidation of pyrogallol by 50%, relative to the control, was defined as one unit of SOD activity. The enzymatic activity was expressed as U/mg of protein.

##### 2.7 Determination of catalase (CAT) activity

Catalase activity was measured as described earlier (Aebi, 1984). Sample aliquots of supernatant were mixed with a solution containing 30% H<sub>2</sub>O<sub>2</sub>, milli-Q water and buffer 5 mM Tris EDTA, pH 8.0. The absorbance was determined by spectrophotometry at 240 nm for 60 seconds. The enzymatic activity was expressed as mmol/ min/mg of protein

##### 2.8 Statistical analysis

Standard deviation for triplicate values has been done and the results are expressed as mean ± S.D.

#### 3. Results & Discussion

##### 3.1 Effect of seaweed extract on ulcer models

The anti-ulcer effect of seaweed extracts was evaluated by comparing the degree of gastric ulceration in treated groups and control animals as assessed in histopathology. It was observed that animal specimens subjected to Ethanol/HCl showed histopathological lesions including degeneration, hemorrhage, and edematous appearance of the gastric tissue. Those pretreated with seaweed extract (0.5 g/kg) exhibited significant protection against all such damage to the mucosa. (Fig.1). Oxidative stress is one of the main factors and plays an important role in the pathogenesis of gastric injury. HCl/ethanol induced gastric lesions are thought to arise as a result of direct damage of gastric mucosal cells, resulting in the generation of free radicals and hyper oxidation of lipid (Jainu & Devi, 2006). The gastric lesions in the stomachs of ethanol-treated rats were significantly higher when compared to the normal control. Fewer ulcer lesions (Fig. 2) were observed in seaweed extract - treated groups. Severe blood vessel damage and tissue damage with 15-17 lesions were observed in positive control, whereas lesser tissue and blood vessel damage was noticed for seaweed extract -treated samples. They also suffered fewer (2-3) lesions.

It is thus inferred that the bioactive compounds in the seaweed extract have anti-ulcer properties offering protection to treated samples. The anti-ulcer effect may be due to the presence of sulphated polysaccharides and other potent compounds in the seaweed extract. In the ethanol-induced ulceration study, pretreatment with seaweed extracts produced a significant decrease in number of ulcers, ulcer score and ulcer index (Table 1). The ulcer inhibition was found to be 80% at a dose of 0.5g/kg for both seaweeds treated groups (Table 1). The result shows that the SOD, CAT, and GSH levels in the ethanol treated groups were significantly lower than that of the control group.

Seaweeds increased the activity of antioxidant enzymes (Table 2), which in turn demonstrates that the extract is more efficient in reducing oxidative damage, and therefore, has a greater potential to promote higher quality gastric healing. Increase in gastric volume, low pH value and acidity are the major parameters in assessing severity of ulcer. Increase in pH and reduced gastric volume is highly correlated with effective anti-ulcer activity. In our results we observed an elevation in pH of 6 and 7 and decreased acidity (Table 3) which could be an indication of protection offered by seaweed extracts against gastric ulcer.

Treatment	No. of ulcer	Ulcer score	Ulcer index	Ulcer inhibition (%)
Normal control	0 ± 0	0 ± 0	-	-
Positive (HCl/ethanol induced)	17 ± 0.5	3 ± 0.8	20 ± 0.8	-
Standard drug treated	6 ± 0.2	2 ± 0.2	6 ± 0.3	70
<i>Sargassum wightii</i>	3 ± 0.5	1 ± 0.8	4 ± 0.6	80
<i>Turbinaria conoides</i>	3 ± 0.5	1 ± 0.8	4 ± 0.7	80

Table 1: Effect of extracts on ulcer score, ulcer index and ulcer inhibition in ulcer induced rats. Values are expressed as mean ± S.E.M

Group	SOD (U/mg of protein)	Catalase (mmol/min/mg)	GSH (µg/g of tissue)
Normal control	1735 ± 76	2918 ± 43	452 ± 28
Ethanol/HCl induced	246 ± 98	233 ± 74	209 ± 48
Standard drug	1234 ± 212	2734 ± 82	521 ± 36
<i>Sargassum wightii</i>	1308 ± 201	2897 ± 47	513 ± 38
<i>Turbinaria conoides</i>	1329 ± 233	2806 ± 77	496 ± 28

Table 2: Effect of seaweeds extracts treatment on superoxide dismutase (SOD), catalase (CAT) and non-protein sulfhydryl groups (GSH) at ulcer site induced by ethanol and HCl in rats. Results expressed as mean ± S.E.M

Treatment	Gastric content(ml)	pH of gastric content	Total acidity (mEq/L)
Normal control	4 ± 0.2	7 ± 0.1	48.32 ± 0.2
Positive control	8.2 ± 0.3	5.5 ± 0.2	73.23 ± 0.3
Standard drug	5.6 ± 0.3	6.5 ± 0.3	38.26 ± 0.2
<i>Sargassum wightii</i>	5.4 ± 0.2	7 ± 0.3	42.38 ± 0.1
<i>Turbinaria conoides</i>	5 ± 0.2	6 ± 0.3	35.48 ± 0.1

Table 3: Effect of seaweed extracts on gastric secretion, pH of gastric content and total acidity. Results as mean ± S.E.M

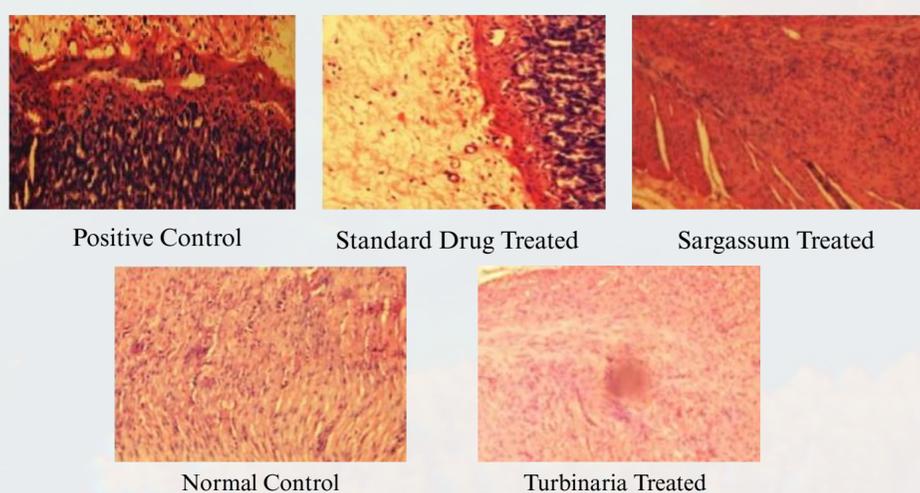


Figure 1: Histopathology of gastric mucosa



Figure 2: Antiulcer activity on gastric mucosa

#### 4. Conclusion

The present study comprehensively demonstrates the potent anti-ulcer activities of extracts derived from *Sargassum wightii* and *Turbinaria conoides*. These findings are strongly supported by both biochemical and histopathological analyses conducted on the stomach wall tissues of experimental rat groups subjected to different treatments. The biochemical assessments revealed significant alterations in key gastric parameters, such as antioxidant enzyme levels, gastric acid secretion, and mucosal protective factors, indicating the protective role of these extracts in ulcer management. Furthermore, histopathological examinations provided substantial evidence of tissue regeneration and reduced ulceration in treated groups compared to controls. These results collectively highlight the therapeutic potential of *Sargassum wightii* and *Turbinaria conoides* extracts in mitigating gastric ulceration, paving the way for their possible application in gastroprotective drug development.

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Image credit: Dr. Mani Murali